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MINIMUM FLUIDISATION VELOCITY IN PACKED -FLUIDISED BED REACTORS

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An experimental determination of the velocity of minimum fluidisation of cylinder-packed fluidised bed reactors has been made. Two columns of equal lengths but of different diameters were employed. The columns were charged with three sizes of cylindrical packings and five grades of sand. The fluidising medium was air.

The experimental results on velocity of minimum fluidisation were compared with the values available from literature for conventional fluidised beds.

Key words: Minimum fluidisation velocity, Interstitial fluidisation, Pressure drop.

INTRODUCTION

A packed-fluidised bed is a modification of the conventional fluidised bed, in which particulate material is fluidised in the interstices of stationary packings. The addition of fixed packings to a fluidised bed results in significant changes in quality and performance of the fluidised beds. Some of the parameters of interest for the process design of such reactors are: pressure drop, velocity of minimum fluidisation, bed expansion, interstitial and bed porosities.

The limited published work in packed-fluidised beds include studies of pressure drop, bed expansion, gas and solids mixing phenomena [3,5,6,7,8,9,10,11,16]. The pressure drop across such reactors, under both fixed bed and fluidised bed conditions, has been reported earlier by the current author [1,2]. The present investigation shall deal with the quantitative determination of velocity of minimum fluidisation in fixed-fluidised bed reactors.

EXPERIMENTAL

Equipment. A line diagram of the experimental arrangement is shown in Fig. 1. Two columns of varying diameters but of almost same lengths were used in this study. The columns were made from perspex tubing of 0.3 cm wall thickness. The diameter and length of the small column were 9.0 cm and 32.96 cm respectively, whereas the respective diameter and length for large column were 11.45 and 33.17 cm.

Compressed air at a pressure of 4-5 kg/cm^2 was passed through an air filter and reduced in pressure to 1 kg/cm^2 before entering a bank of rotameters. The bank consisted of three rotameters covering overlapping flow ranges. On leaving the rotameters, the air passed into a flow distributor at the base of the test section. The flow distributor was a wooden conical expansion section, packed with 0.3 cm steel spheres. The packing rested on a fine mesh support at the inlet of the conical section. The upper metallic flange housing a porous plastic plate (0.5 cm thick) was placed at the outlet of packed expansion section and was fitted to the lower steel flange at the base of wooden section with the help of six tie-rods.

Each column was held by steel flanges having 0.15 cm deep grooves, into which the ends of the column were inserted. Slow setting adhesive was used to seal the column in the grooves. The assembly was firmly secured by six tie-bars having counter-sunk screws at the bottom and bolted at the top. To avoid leakage of air, two rubber 'O' rings were provided on the lower surface of the steel flange of the column.

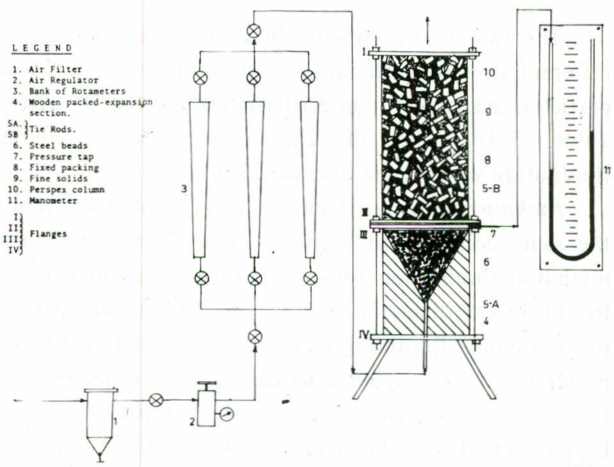

Fig. 1.

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In order to make pressure drop measurements, a pressure tap was provided slightly above the porous plastic support in the upper steel flange of the flow distributor and was connected to one limb of the water manometer. The other limb of the manometer was left open as the test-section was also open to atmosphere. The pressure drop so measured gave the pressure drop across the bed.

Procedure

The test-section was packed with large diameter packings. The fine particles, thoroughly washed and oven dried, were poured into the bed until these reached the level of packings.

The column was centred on the flow distributor and secured to it by using three quick-release wrenches. A very small air velocity (at a pressure of 1 kg/cm^2) was adjusted on a rotameter. The pressure drop across the bed was noted on the manometer. The air flow rate was increased slowly and pressure drop measurements were made. A linear drop in pressure was observed until the point of minimum fluidisation was reached when the weight of fluidised solids was equal to the pressure drop across the bed. (The point of minimum fluidisation was also verified by observing pressure drops while decreasing air velocity from an initial higher value.) The procedure was also repeated for the second column and for all possible combinations of packing and fluidised solids.

The packing used in this study consisted of (0.62 x 0.62) cm and (1.91 x 1.91) cm brass cylinders and (0.01 x 1.01) cm aluminium cylinders. The fluidised solids were of three sizes, namely, 664, 312, and 177 μ of Lawerncepur sand and two sizes (144, 89 μ) of Ravi sand.

DISCUSSION

The values of minimum fluidisation velocity for three different sizes of stationary packing and five grades of sand particles, available for interstitial fluidisation, are given in Table 1. The effect of various parameters of minimum fluidisation velocity are discussed below:

Packing size. From Table 1, it can be observed that for the same column and fluidised solids sizes, the values of minimum fluidisation velocity is higher for small size. So, for 11.45 cm diameter column and 177 μ sand particles, the minimum fluidisation velocity for (1.91 x 1.91) cm packing is 14.38 cm/sec whereas its value is 18.95 cm/sec for (1.01 x 1.01) cm cylinders. Also, respective values of U_{mf} for (1.91 x 1.91) cm and (1.01 x 1.01) cm cylinders is 32.24 cm/sec and 36.64 cm/sec. The reason for the difference in the values of minimum fluidisation velocity could be attributed to the fact that the relative freedom of movement of fine solids in the interstices of small-sized packing is much more restricted in comparison to large-sized packing and hence higher air velocity is needed to initiate interstitial fluidisation in small packing size. The same effect is displayed by 312 μ particles in smaller column.

Size of fine particles. In general it is observed from Table 1, that for fixed packing and column sizes, the Umf values are higher for beds using large size solids than for beds employing small size fine particles. So for both beds using (1.91 x 1.91) cm packing, the values of minimum fluidisation velocity are higher for 664 μ than 177 μ particles. Also for beds using (0.62 x 0.62) cm packing, the magnitudes of Umf for 144 μ particles are higher than those for 89 μ. This observation could be attributed to the fact that interstitial movement of large size fluidised solids is more restricted as compared to small size fluidised beds employing small size fine particles in fixed orientation of packing.

The exception to the above generalisation are observed in the case of small diameter column, employing (1.91 x 1.91) cm brass and (0.01 x 1.01) cm aluminium cylinders and fine sand particles of 312 μ and 177 μ. In these cases, the velocity of minimum fluidisation is lower for 312 μ than 177 μ; the discrepancy of the above generalisation may be due to the fact that 177 μ particles were found more angular in shape (when observed under the microscope) as compared to 312 μ. Therefore, the relative freedom of movement in the case of 177 μ particles was relatively more restricted and hence resulted in higher values of U_{mf}.

Column diameter. The results given in Table 1 also demonstrate the effect of size of column upon the velocity

Table 1. Experimental values of minimum fluidisation velocity.

System		Large diameter column (I.D. = 11.45 cm)	Small diameter column (I.D. = 9.0 cm)
Packing size(cm)	Particle size (micron)	Velocity of minimum fluidisation, U_{mf} (cm/sec)	Velocity of minimum fludisation, U_{mf} (cm/sec)
1.91x1.91	664	52.08	51.89
1.91x1.91	312		14.94
1.91x1.91	177	14.38	32.24
1.01x1.01	312	–	19.97
1.01x1.01	177	18.95	36.64
0.62x0.62	144	6.80	7.00
0.62x0.62	89	5.59	4.56

Table 2. Comparison of velocity of minimum fluidisation for fixed-fluidised beds and conventional fluidised beds.
Density of air at room temperature = 0.0012 (gm/cm^3)
Viscosity of air at room temperature = 0.00018 (Poise).

Particle size (microns)	Particle density, ρs (gm/cm^3)	Velocity of minimum fluidisation. U_{mf} (cm/sec)				
		Richardson [4]	Leva [12]	Rowe & Henwood [15]	Davies & Richardson [4]	Present work, small diameter column with packings (1.91 x 1.91) and (0.62x0.62) cm
664	3.41	48.33	47.34	66.34	63.88	51.89
312	3.38	10.57	11.58	14.51	13.98	14.94
177	3.58	3.60	4.45	4.94	4.76	32.24
144	3.10	1.29	1.74	1.78	1.78	7.00
89	3.30	0.84	1.17	1.15	1.11	4.56

of minimum fluidisation. It may also be observed that with the exception of systems using 177 μ particles, the effect of column diameter on Umf is almost negligible. It is believed that this variation in behaviour of Umf for 177 μ particles is due to the reasons mentioned earlier in section 3.b.

The experimental results regarding the velocity of minimum fluidisation in fixed-fluidised bed reactors obtained from the present investigation were also compared with those given by theoretical correlations developed for fluidised beds without employing fixed packings [4,12,14,15]. Such comparison can be seen in Table 2. From the table, it is evident that the values of Umf for the present work are higher than those reported for conventional fluidised beds. This observation is in line with the conclusions reported earlier by Pillai and Rao [13].

CONCLUSION

The velocity of minimum fluidisation in fixed-fluidised beds employing cylindrical packings and sand particles is found to be dependent on the size of fluidised solids and packing. The effect of column diameter is insignificant.

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Notations

Umf – Velocity of minimum fluidisation, cm/sec.
ρs – Particle density, gm/cm^3

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